

ATLAS AND CMS GROUP HIGHLIGHTS.

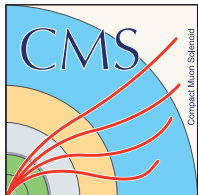


83rd DESY Physics Research Council meeting

James Robinson

on behalf of the DESY ATLAS and CMS groups

Hamburg, 21st-22nd March 2017

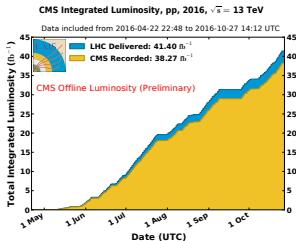


- ATLAS and CMS groups are active across a wide range of areas
 - Computing & software
 - Detector operation
 - Detector upgrade
 - Physics object calibration & performance
 - Physics data analysis
- Detector upgrade will be covered in Guenter's talk
- This talk will cover a small subset of the other ongoing activities

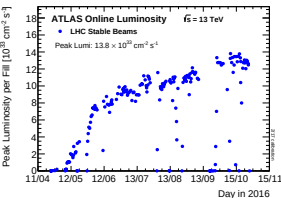


LHC STATUS

LHC operation



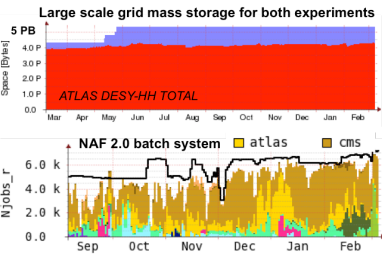
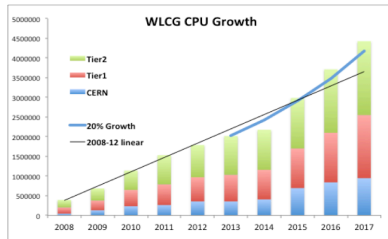
- LHC delivered $\sim 40 \text{ fb}^{-1}$ of pp collisions in 2016
- Peak luminosity $13.8 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- ATLAS/CMS each recorded $> 35 \text{ fb}^{-1}$
→ data quality efficiency over 90%



- Restart planned for June: aiming for $\sim 45 \text{ fb}^{-1}$ during 2017

LHC Computing at DESY

- LHC performance in 2016 tested ATLAS/CMS computing resources
- Increase of 20% on top of planned increase
 - DESY one of the sites able to meet this
- DESY now 3rd (4th) overall in WLCG provision to CMS (ATLAS)



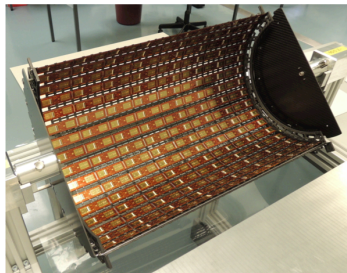
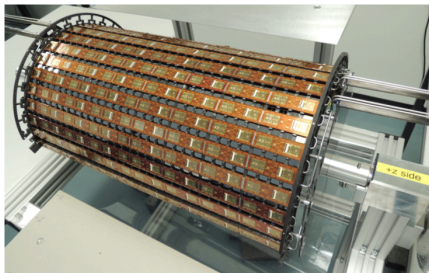
- DESY manages around 14 PB of HEP data
 - including 7PB CMS + 6PB ATLAS
 - developing dCache storage system
- NAF provides ~ 7000 CPUs
 - new high performance scratch storage

DETECTOR OPERATIONS

CMS Phase 1 upgrade: new pixel vertex detector

Upgrade for higher luminosities and improved performance

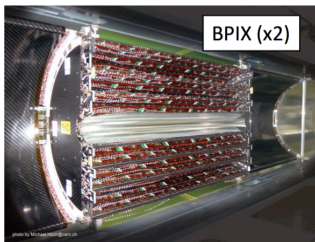
- New detector improves track and vertex resolution
- Si-modules for 4th barrel layer built entirely in Germany:
 - 50% DESY & Hamburg; 50% Karlsruhe & Aachen



Integration at PSI: Barrel Pixel layer-4 half-shell equipped with 256 DESY+UniHH modules

CMS shutdown work: new pixel detector

- New pixel detector is installed
 - Barrel pixel detector: 28/02-02/03
 - Forward pixel detector: 06/03-10/03
- Preparing for LHC data taking
 - April: detector commissioning, cosmics runs
 - May-June: commissioning with splashes, non-stable and stable beam



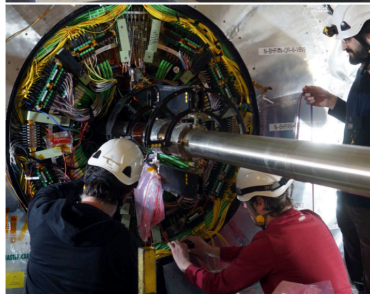
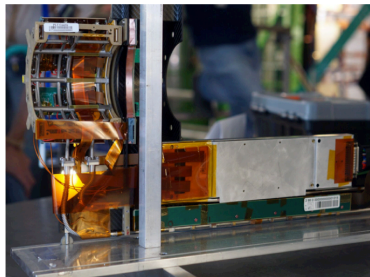
Successfully
installed in CMS

CMS BCM1F: Online luminosity and beam background

- Multipurpose diamond detector
 - fast online luminosity and beam-background measurement (for CMS & LHC)
 - first application of a large number of single-crystal diamond sensors
 - Run-I: 8 single-crystal sensors
 - robust, proven technology
 - Run-II: 24 two-pad single-crystal sensors
 - ran at reduced voltage due to erratic currents
- For 2017/18: system rebuilt using 3 types of sensors (redundancy and robustness for expected luminosity)
 - 10 poly-crystal diamond sensors
 - 4 single-crystal sensors (remetallized)
 - 10 silicon sensors

Developed at DESY





> Sensors

- processing and metallisation by RD42
- characterisation in Zeuthen

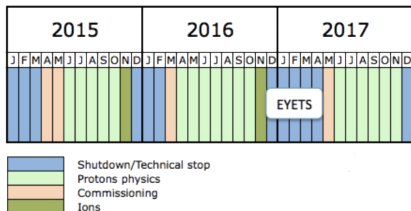
> C-shapes

- produced at CERN
- electrical tests and mounting of components and sensors in Zeuthen

Successfully installed in CMS last week

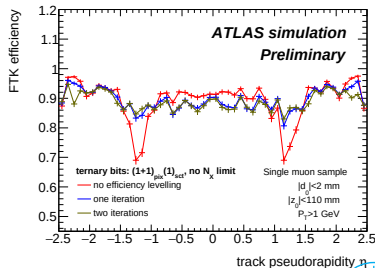
ATLAS Fast TrackKer (FTK)

Reconstruct tracks with $p_T > 1$ GeV for HLT at 100 kHz

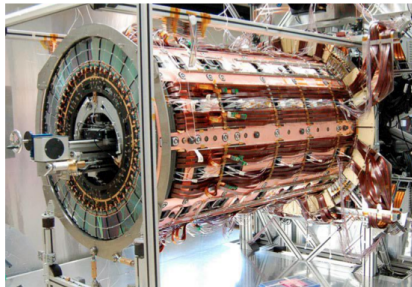


- Track-based decisions early in the HLT → improved performance
- Use “bank” of known hit patterns
- Optimise pattern bank to improve efficiency

- FTK hardware being commissioned and installed
- 50% of system in 2017
- Full installation in 2018



ATLAS Semi-Conductor Tracker (SCT)



Aim: optimal performance in conditions beyond original design

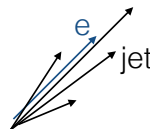
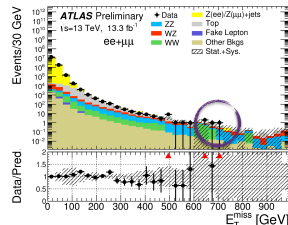
- 99.9% data taking efficiency in 2016
- Ongoing development work for Run 2 & Run 3

Ongoing work in DESY group

- Radiation dose increases non-uniformity across SCT
→ need per-channel calibration
- Non-collision backgrounds can produce fake jets
→ reject using timing difference in SCT end-caps

PHYSICS OBJECT PERFORMANCE

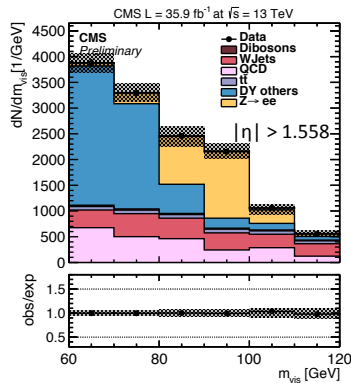
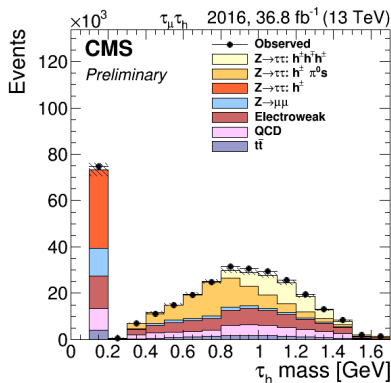
- $Z \rightarrow ee$ (+jets) events do not have real MET
- High MET tail nevertheless evident
 - important/difficult background for new physics searches with high MET
- Incorrect e-jet overlap removal
 - spurious MET
 - important source of MET tail
 - improved overlap → reduced the tail
 - investigating other sources of tails



DESY jet performance contributions

- GSC: jet properties ↔ p_T response correlations: improve resolution
- b-tagging: calibration of light-jets with negative-tag method

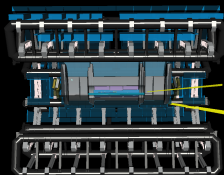
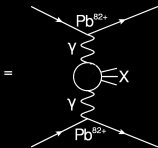
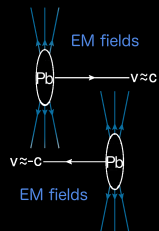
- DESY responsible for $e \rightarrow \tau_h$ and $\mu \rightarrow \tau_h$ fake rates
- Not well modelled by simulation
- Lepton fake rate scale factors derived from $Z \rightarrow \ell\ell$ events
→ bring simulation into agreement with data



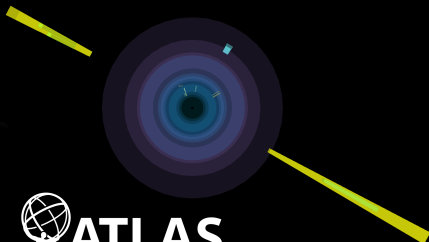
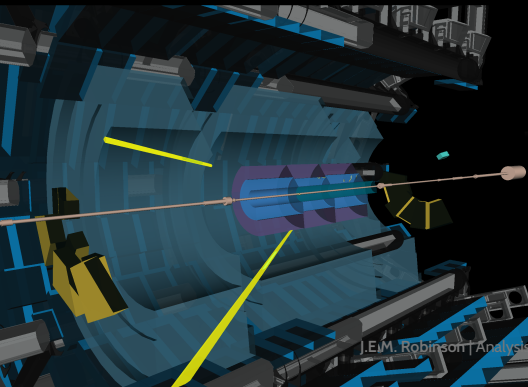
ANALYSIS: STANDARD MODEL AND TOP

ATLAS: Light-by-light scattering [5.02 TeV]

sub. Nature Phys.



- > LBL candidate: two $E_T = 4.9$ GeV back-to-back photons with no additional activity
- > Field strength of up to 10^{25} V m⁻¹!

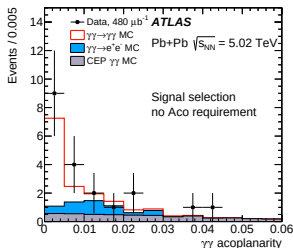
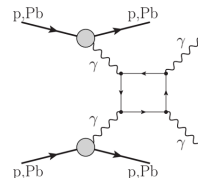


 **ATLAS**
EXPERIMENT



First direct evidence for elastic photon scattering

- SM measurement in PbPb collisions
- Dedicated trigger: calorimeter energy + MBTS veto
- Exclusivity veto: events with tracks rejected

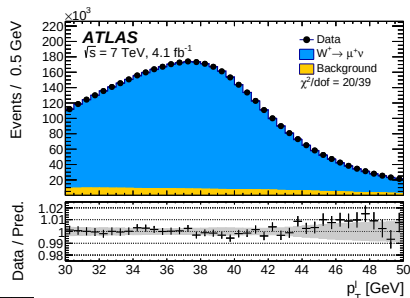
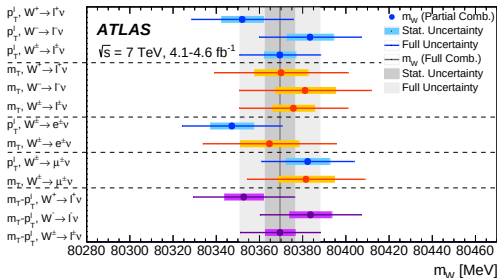


- σ (measured): $70 \pm 20(\text{stat.}) \pm 17(\text{syst.}) \text{ nb}$
- σ (theory): $49 \pm 10 \text{ nb}$

Observed (expected) significance: 4.4 (3.8) σ

First LHC W-mass measurement

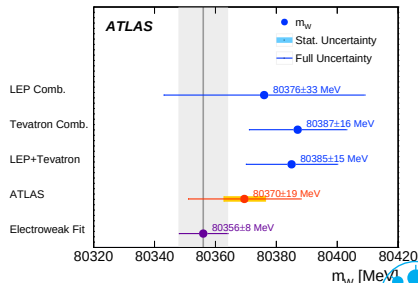
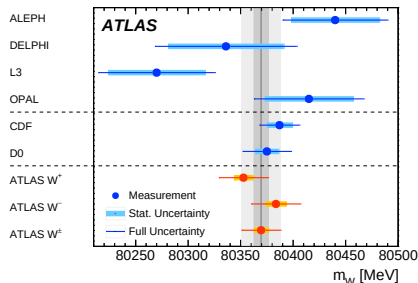
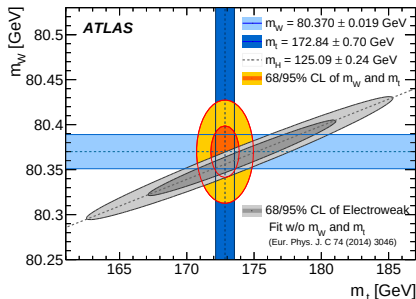
- Final state lepton (e/μ) + MET
- Control backgrounds at 5% level
- Sensitive distributions: lepton p_T , transverse mass, MET



- χ^2 minimisation MC wrt data for range of m_W

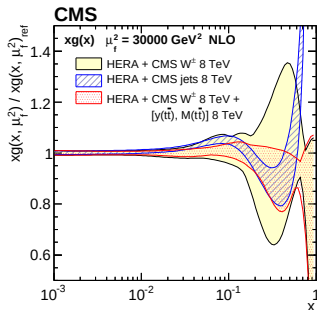
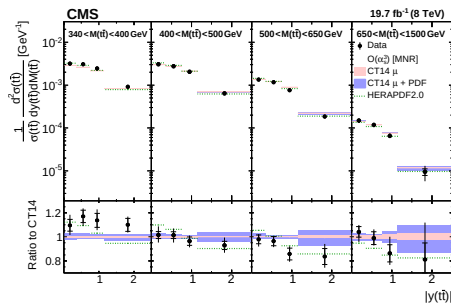
$$m_W = 80.370 \pm 0.019 \text{ GeV}$$

- New measurement reaches precision of CDF
→ world leading measurement
- Good agreement with SM



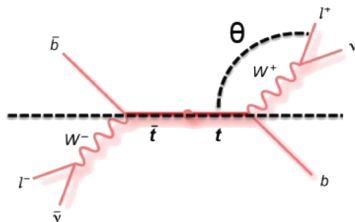
First PDF fit using 2D $t\bar{t}$ cross sections (stronger constraints than 1D)

- Stringent tests of pQCD, enhance sensitivity to BSM physics
- Double-differential $t\bar{t}$ measurement (bin events in two variables)
- Constraints from 2D $t\bar{t}$ competitive to those from jet data

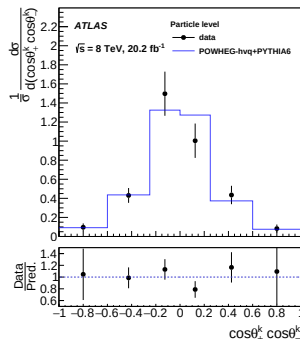


Measure production spin density matrix

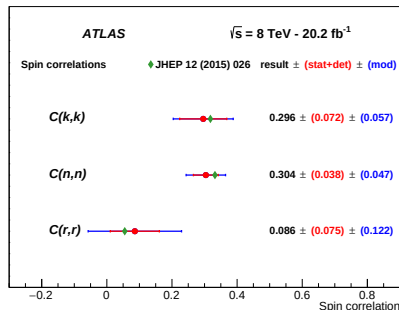
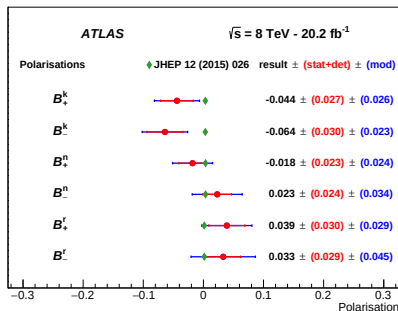
- Express matrix in terms of spin and polarisation coefficients
- Decompose top quark polarisations along orthogonal axes



- Construct angular distributions sensitive to polarisation



- Extract polarisations (and correlations) from distributions

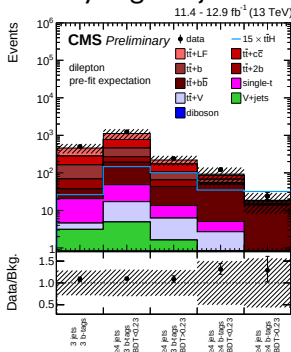
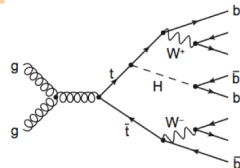


- 10 of 15 observables measured for the first time
- First evidence of transverse spin correlations **5.1 σ** from zero
- Good overall agreement with NLO SM predictions

ANALYSIS: HIGGS

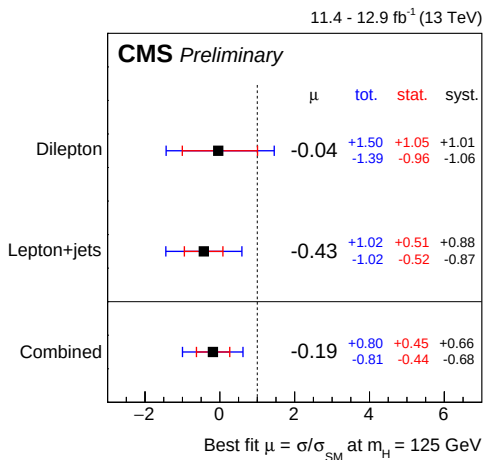
Vital step towards verifying the SM nature of the Higgs boson

- Only direct access to top-Higgs coupling
- $t\bar{t}H(\rightarrow bb)$: small cross section (despite $H \rightarrow bb$ BR)
- Very large $t\bar{t}$ +jets background



- Categorize via $t\bar{t}$: l+jets, dilepton channels
- Complex final state: classify in regions of jet multiplicity and number of b-jets
- Use multivariate analysis techniques to further improve sensitivity
 - BDT, Matrix Element Method

Extract best-fit signal strength ($\mu = \sigma/\sigma_{SM}$)



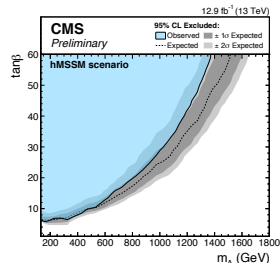
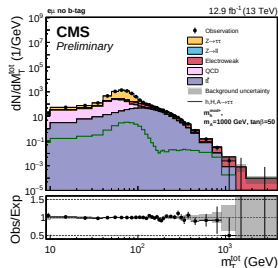
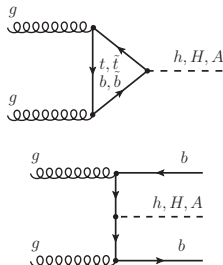
- > Simultaneous maximum likelihood fit across all categories
- > Results compatible with SM expectation within 1.5 std.
- > Interpret as upper limit on cross section:

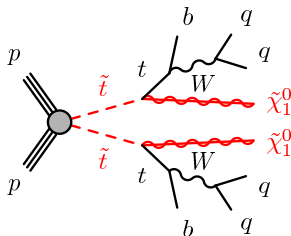
$$\sigma_{t\bar{t}H} \leq 1.5\sigma_{SM} \quad (1.7 \text{ exp.})$$



ANALYSIS: BEYOND THE STANDARD MODEL

- Preliminary result based on 12.9 fb⁻¹ of 2016 data
- DESY is responsible for the $e\mu$ channel.
- Exclusion in m_A - $\tan\beta$ parameter space
 $\rightarrow$ hMSSM scenario: assume boson at 125 GeV is lightest MSSM state

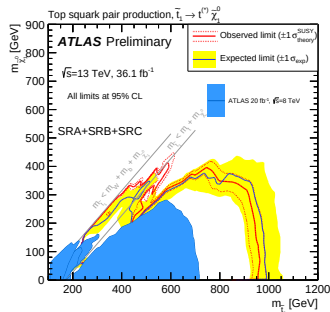
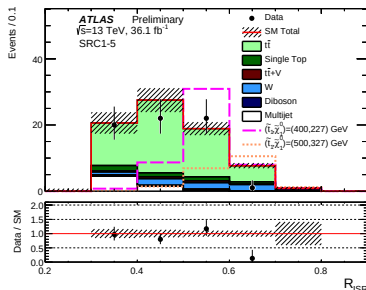




- Direct stop pair production: $\tilde{t} \rightarrow t + \tilde{\chi}_1^0$
- Compressed region: $\Delta m_{\tilde{t}, \tilde{\chi}_1^0} \simeq m_t$

$$R_{\text{ISR}} = E_T^{\text{miss}} / p_{T\text{ISR}} \propto m_{\tilde{\chi}_1^0} / m_t$$

- Strong ISR boost used to reject $t\bar{t}$
- Exclusion limits from R_{ISR} shape fit



SUMMARY AND OUTLOOK

Summary and outlook

- The LHC performed exceptionally during 2016
- Record luminosity recorded by both ATLAS and CMS
- DESY computing exceeded expectations by 20%
- The DESY ATLAS and CMS groups have made significant contributions to detector operation, software and data analysis
- Many ongoing analyses aiming for publication in time for spring & summer conferences

